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Description

Device and method for diagnosing obstructions in channels of a micro heat exchanger

It is known that deposits (fouling) in heat exchangers disrupt the effectiveness of the heat transfer between the fluids involved in the heat exchange. The same effects are to be observed in micro heat exchangers with microchannels of which the diameter is < 1 mm, but in such devices this leads to the blockage of individual channels or of all channels. Considering the fact that micro reactors are also used in particular for extreme exothermic reactions, explosive mixtures or toxic chemicals, it is understandable that early detection is necessary as to whether a safe tempering can no longer be guaranteed as a result of the obstruction of the heat exchangers which are used for such purposes as delay lines. To increase throughput microchannels are frequently connected in parallel in micro heat exchangers. An even distribution of the fluids on these microchannels is achieved by their relatively high flow resistance. If individual microchannels are now blocked, the heat transfer surface and thereby the efficiency of the heat transfer is reduced. The efficiency is calculated from the capacity flows (mass flow x specific heat capacity) of the fluids involved in the heat exchange as well as from their temperature on entry into and exit from the heat exchanger. The fluid temperatures cannot however be recorded directly in the microchannels since the temperature sensors currently available are so large that they would block at least a major part of the channel cross section and that even with slight contact with the channel wall the temperature reading is likely to be falsified as a result of heat conductance.

The underlying object of the invention is thus to make possible a simple diagnosis of obstructions in channels of a micro heat

exchanger.

In accordance with the invention the object is achieved by the device specified in claim 1 for diagnosing obstructions in channels of a micro heat exchanger, with at least one temperature sensor being arranged on the outside of the micro heat exchanger, and an evaluation device being connected to it, which, on the basis of changes to the measured temperature with unchanged entry parameters of the fluids involved in the heat exchange, diagnoses an obstruction. The object is further achieved by a corresponding method specified in claim 4.

By contrast with conventional heat exchangers, the axial heat conductance in the channel wall plays a major role in micro heat exchangers, since the ratio of the wall cross sectional surface to the channel cross sectional surface is greatly increased. The consequence, particularly with materials with good heat-conducting qualities, is greatly reduced efficiencies compared to conventional heat exchangers. In the area of small NTUs (Number of Transfer Units), i.e. for small ratios of the product of heat transfer surface and heat transfer coefficient to heat capacity flow, the efficiency drops as the NTU falls, while it remains constant in the area of large NTUs. There is always a laminar creeping flow in the micro channels so that the coefficient of heat transfer is independent of the flow velocity. If a few micro channels are now obstructed, the flow velocity actually increases in the other channels; however the coefficient of heat transfer remains constant and the transmitted heat volume falls because of the reduced heat transfer surface. Since the heat capacity flow remains constant, the efficiency decreases.

The invention now makes use of the fact that, because of the high heat conductance, the temperature of the micro heat exchanger wall with unchanged entry parameters of the fluids

involved in the heat exchange, which means with constant mass flows and constant fluid entry temperatures, and with sufficiently small NTU (around > 5), is a measure for the efficiency of the heat exchanger. At the same time the temperature, also because of the high heat conductance in the wall, in micro heat exchangers is relatively homogeneous, so the efficiency can be deduced on the basis of the temperature of the micro heat exchanger, and the temperature in its turn can be recorded significantly more easily since installing the temperature sensor on the exterior of the micro heat exchanger does not present any problem. A further advantage lies in the fact that the temperature sensor does not come into contact with the fluids so that it is not necessary to worry about the resistance to chemicals or the catalytic effect of the temperature sensor. With very large micro heat exchangers the temperature can be measured with a number of temperature sensors at a number of points.

With an alternative device for diagnosing obstructions in channels of a micro heat exchanger the obstructions are not diagnosed on the basis of changes in the measured temperature; Instead a closed loop control device is connected to the temperature sensor which controls the mass flow of a fluid involved in the exchange of heat in the sense of keeping the measured temperature constant, with obstructions being diagnosed as a result of changes to the mass flow.

If the micro heat exchanger is used as a delay element for chemical reactions, the reaction heat to be fed in or removed must additionally be taken into account, something which can be done by a more complex evaluation (fuzzy logic, neuronal networks).

For further explanation of the invention reference is made below to the figures of the drawing, The individual figures

show

Figure 1 a first exemplary embodiment and

Figure 2 a second exemplary embodiment of the micro heat exchanger in accordance with the invention.

Figure 1 shows a micro heat exchanger 1 with an inlet 2 and an outlet 3 for a fluid to be cooled 4 and an inlet 5 and an outlet 6 for a cooling fluid 7. Within the micro heat exchanger 1 parallel microchannels 8 are embodied in each case between the inlets 2 and 3 or 5 and 6, each with a channel diameter of < 1 mm. On the outside of the micro heat exchanger 1 a temperature sensor 9 is arranged, which measures the temperature on the micro heat exchanger wall and is connected to an evaluation unit 10. This sensor detects a reduction in the efficiency of the heat exchanger 1 if the measured temperature changes with constant mass flows and constant fluid entry temperatures.

The exemplary embodiment shown in Figure 2 of the inventive micro heat exchanger differs from the device shown in Figure 1 in that, instead of the evaluation unit 10, a closed-loop control unit 11 is provided, which uses a control element 12 to regulate the mass flow of the cooling fluid 7 in the sense of keeping the temperature of the micro heat exchanger 1 constant with the temperature sensor 8.